SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

JHRP-86/14

INFORMATIONAL REPORT

STABL5/PC STABL5 USER MANUAL

James R. Carpenter

PURDUE UNIVERSITY

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Information Report

STABL5/PC STABL5 USER MANUAL

To: H. L. Michael, Director
Joint Highway Research Project

October 14, 1986
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From: C. W. Lovell
Research Engineer
Joint Highway Research Project

The attached report instructs in the use of STABL5/PC STABL5. The new program contains all of the options of STABL4/PC STABL4, and adds a better method of slices option (Spencer). It also makes some minor improvements in the tieback options and plotting routines of the previous software.

It is recommended that the IDOH replace their present STABL operating routines with STABL5/PC STABL5.

Respectfully submitted,

CW Lovell

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Informational Report

STABL5/PCSTABL5 USER MANUAL

by

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STABL5/PCSTABL5 USER MANUAL

ABSTRACT

This report describes the operation of the two-dimensional, limit equilibrium slope stability programs, PCSTABL5 and STABL5. These new versions of STABL incorporate analysis of slopes using Spencer's method of slices. A short summary of the capabilities of the program is presented and the newest versions are compared to earlier STABL versions. Operation of the program using the new Spencer routines is presented along with example problems. Modifications to the tieback input format are also discussed. In addition, instructions for operating the microcomputer based programs PCSTABL5 and the PCSTABL5 plotting program, PLOTSTBL, are presented. Finally, Appendix A lists the definitions of the variables and subroutines used in the programs.

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
I.1 General Capabilities of STABL5/PCSTABL5	2
I.2 Comparison of STABL5/PCSTABL5 With STABL4/PCSTABL4	4
I.3 Availability of Programs	4
II. SPENCER'S METHOD OF SLICES	7
II.1 SPENCR Input Format	9
II.2 SPENCR Input Restrictions	9
II.3 SPENCR Error Code	10
II.4 Example Problems	10
III. MODIFICATION OF TIEBACK INPUT	29
III.1 Revised TIES Input Format	30
III.2 Revised TIES Input Restrictions	30
III.3 Revised TIES Error Codes	31
IV. INTRODUCTION TO PCSTABL5	35
IV.1 PCSTABL5 Versions	35
IV.2 Comparison of PCSTABL5 to STABL5	36
V. RUNNING PCSTABL5	39
V.1 Hardware and Software Requirements	39
V.2 Diskette Contents	40
V.3 Creation of Input Files	41
V.4 Running PCSTABL5	42
VI. PLOTTING ROUTINE FOR PCSTABL5 - PLOTSTBL	45
VI.1 Hardware and Software Requirements	45
VI.2 Running PLOTSTBL	46
APPENDIX A - Variable and Subroutine Definitions	A-1

I. INTRODUCTION

The purpose of this document is to describe the procedures for analyzing the stability of slopes and retaining walls using Spencer's method of slices as recently implemented in the slope stability program, STABL. The newest versions of the STABL program, STABL5 and PCSTABL5, are the only versions to contain the Spencer method of slices. This user manual focuses mainly on the use of the new Spencer routines and is intended to serve as a supplement to the most recent documentation on STABL:

Lovell, C.W., Sharma, S.S., and Carpenter, J.R. (1985), "Introduction to Slope Stability Analysis with STABL4", Internal Report, Purdue University, January 25, 1985, (formerly JHRP-84-19).

Carpenter, J.R. (1985), "PCSTABL4 User Manual", Joint Highway Research Project No. JHRP-85-7, School of Civil Engineering, Purdue University, West Lafayette, Indiana, May, 1985 .

Detailed information concerning the derivation, and method of solution of Spencer's method of slices implemented in STABL5 and PCSTABL5 may be found by referring to:

Carpenter, J.R. (1986), "Slope Stability Analysis Considering Tiebacks and Other Concentrated Loads", MSCE Thesis, Purdue University, West Lafayette, Indiana, 1986.

Carpenter, J.R. (1985), "STABL5...The Spencer Method of Slices: Final Report", Joint Highway Research Project No. JHRP-85-17, School of Civil Engineering, Purdue University, West Lafayette, Indiana, August, 1985.

This manual describes the input format and error codes associated with the new Spencer routines. Two example problems including input files, output files, and plots are included to familiarize the user with the new routines. A description of some minor enhancements with respect to the tieback routines follows the discussion of the use of the new Spencer routines. This manual also describes execution of PCSTABL5 on a microcomputer, along with the capabilities, and hardware and software requirements of the PCSTABL5 program.

The "STABL User Manual", JHRP-75-9, is required for execution of STABL5/PCSTABL5. This reference, along with those listed above, describes the program's limitations, assumptions, creation of input files, and provides several example problems. Three other useful references on the STABL programs are:

1). "Computer Analysis of General Slope Stability Problems", JHRP-75-8;

2). "Computerized Slope Stability Analysis for Indiana Highways", Vol. 1, JHRP-77-25; and

3). "Three-Dimensional Slope Stability Analysis", JHRP-81-17.

I.1 General Capabilities of STABL5/PCSTABL5

The STABL5 and PCSTABL5 programs are written in FORTRAN and calculate the factor of safety against slope failure by a two-dimensional limiting equilibrium method. The calculation of the factor of safety against slope instability is performed using the Simplified Bishop method of slices, which is applicable to circular shaped failure surfaces, the Simplified Janbu method of slices, which is applicable to failure surfaces of a general shape, or Spencer's method of slices which is applicable to surfaces having a circular or general shape.

STABL5 and PCSTABL5 feature unique techniques for random generation of potential failure surfaces for subsequent determination of the more critical failure surfaces and their corresponding factors of safety. Circular, irregular and sliding block surfaces may be generated and analyzed using either a random search technique or specific input of the coordinates of a given potential failure surface.

The programs are capable of handling heterogeneous soil systems, anisotropic soil strength parameters, excess pore water pressure due to shear, static groundwater and surface water, pseudo-static earthquake loading, surcharge and tieback loading.

The tieback loading feature provides for the input of horizontal or near horizontal tieback or line loads for analyzing the overall stability of tied-back or braced slopes and retaining walls. The STABL programs are the only known computer programs with the ability to analyze slopes subjected to tieback or concentrated loads using the Simplified Janbu, Simplified Bishop, and Spencer's method of slices.

Plotted output is provided as a visual aid to confirm the correctness of problem input data. Error messages are generated within the program to pinpoint locations where input data are inconsistent with STABL5/PCSTABL5's input requirements. Free-format data input eases the task of input file preparation, which results in a reduction of input errors.

I.2 Comparison of STABL5/PCSTABL5 With STABL4/PCSTABL4

The STABL5 and PCSTABL5 versions retain all the capabilities and options of the STABL4 and PCSTABL4 versions. STABL5 and PCSTABL5 are the only versions of STABL with the enhanced capabilities of analyzing potential failure surfaces using Spencer's method of slices. In addition, the input format for the tieback option has been modified to allow input and analysis of tie downs or concentrated loads applied to a horizontal ground surface boundary. These changes will be described further in Section III. The list of subroutine and variable definitions has been modified to reflect the recent program changes and is included in Appendix A.

I.3 Availability of Program

STABL5 is available on an unlabeled 9-track tape for IBM or CDC FORTRAN codes at the required recording density, in bpi; fixed block size (URL=80); and, conversion format (EBCDIC or ASCII). PCSTABL5 is supplied on two 5 1/4 inch double-sided, double-density, floppy diskettes, and one single-sided, double-density, floppy diskette. The program is available for all versions of IBM and MS-DOS disk operation systems (DOS), including DOS 1.0 through DOS 3.0. Both programs are supplied to all private firms by Purdue University and may be obtained by contacting:

Jose Thomaz or Prof. C.W. Lovell
Grissom Hall, School of Civil Engineering
Purdue University
West Lafayette, Indiana 47907
Phone: (317) 494-5025 (or 5034)

Both programs are available to all state highway agencies through the Federal Highway Administration and may be obtained by contacting:

Mr. Chien-Tan Chang
Research Development and Technology
Office of Implementation (HRT-10)
FHWA US DOT
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101
Phone: (703) 285-2357

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II. SPENCER'S METHOD OF SLICES

Spencer's method of slices has been incorporated into STABL to enhance the versatility of the program. Spencer's method satisfies both force and moment equilibrium of a sliding mass of soil, whereas the Simplified Janbu and Simplified Bishop methods satisfy only force or moment equilibrium, respectively. Detailed information concerning the derivation, and method of solution of Spencer's method of slices implemented in STABL5 and PCSTABL5 may be found by referring to:

Carpenter, J.R. (1986), "Slope Stability Analysis Considering Tiebacks and Other Concentrated Loads", MSCE Thesis, Purdue University, West Lafayette, Indiana, 1986.

Carpenter, J.R. (1985), "STABL5...The Spencer Method of Slices: Final Report", Joint Highway Research Project No. JHRP-85-17, School of Civil Engineering, Purdue University, West Lafayette, Indiana, August, 1985.

The Spencer option may be invoked by specifying the command "SPENCR" and an estimate of the slope angle. The SPENCR command precedes specification of the surface type and method of solution; i.e., SURFAC, SURBIS, CIRCLE, CIRCL2, RANDOM, BLOCK or BLOCK2. One half the user input slope angle is used by the program as an initial estimate of the slope of the interslice forces.

Since significantly more computation time is required for analysis of potential failure surfaces using Spencer's method of slices than either the Simplified Bishop or Simplified Janbu methods, the most efficient use of STABL5/PCSTABL5's capabilities will be realized if the user first investigates a number of potential failure surfaces using one of STABL's random surface generation techniques which determines the factor of safety using either the Simplified Janbu or Simplified Bishop method of slices. Once critical potential failure surfaces have been identified, they may be analyzed using the SPENCR option in conjunction with either the SURFAC or SURBIS option to obtain a factor of safety (FOS) satisfying both force and moment (i.e., complete) equilibrium. The reasonableness of the solution obtained may be evaluated through examination of the line of thrust calculated by the Spencer routines.

When a user input potential failure surface is analyzed, the program outputs the value of the factor of safety with respect to force equilibrium (Ff), the value of the factor of safety with respect to moment equilibrium (Fm), and the angle of the interslice forces (theta) calculated during iteration along with the value of FOS and theta satisfying complete equilibrium. When a user input potential failure surface is analyzed, the coordinates of the line of thrust, the ratio of the height of the line of thrust above the sliding surface to the slice height for each slice, and the values of the interslice forces are all output. This information allows the user to quickly determine whether or not the line of thrust, and hence the solution, is satisfactory.

The Spencer option may also be used with the STABL options that generate surfaces randomly. However, when the Spencer option is used in conjunction with randomly generated surfaces, only the FOS and angle of the interslice forces satisfying complete equilibrium are output for the ten most critical surfaces. Information regarding the line of thrust, interslice forces or values of Ff, Fm and theta calculated during iteration is not output for randomly generated surfaces; hence the reasonableness of a solution obtained for a randomly generated surface will not be readily apparent. When the reasonableness of the solution of a randomly generated surface is desired, the surface should be analyzed using the SPENCR option in conjunction with either the SURBIS or SURFAC option.

II.1 SPENCR Input Format

The input format for the Spencer option is given below:

COMMAND CARD	SPENCR	Command Code
DATA CARD	Real	Estimate of approximate slope angle with respect to horizontal (deg)

II.2 SPENCR Input Restrictions

The only input restrictions require that specification of the "SPENCR" option occur prior to specification of the method of surface generation and solution, i.e., SURFAC, CIRCL2, etc., and that the slope angle be greater than zero (deg) and less than or equal to 90 (deg).

II.3 SPENCR Error Code

One error code is associated with the Spencer option:

SP01 - An incorrect value for the approximate slope angle has been specified. The slope angle specified must be greater than zero (deg) and less than 90 (deg).

II.4 Example Problems

Two example problems are given below to familiarize the user with the new SPENCR option. The input files used are given along with the outputs of the results. These examples were run using the PCSTABL5 version. Instructions for operating PCSTABL5 on a microcomputer will be discussed in Section V.

The first example analyzes a single potential failure surface while the second example analyzes 75 randomly generated potential failure surfaces. Note that when a single trial failure surface is analyzed, as in Example #1, information concerning the line of thrust is output, while information concerning the line of thrust is not output for randomly generated surfaces. The graphical output produced using the PLOTSTBL program and a Hewlett-Packard plotter is included at the end of each output. Instructions for operating PLOTSTBL are discussed in Section VI.

Example #1 - Input File

```
PROFIL
PCSTABL5 Example Problem #1 Using Spencer's Method
3 3
0. 20. 10. 20. 1
10. 20. 210. 120. 1
210. 120. 240. 120. 1
SOIL
1
125. 125. 300. 40. .5 0. 1
SPENCR
26.
SURBIS
8
10. 20.
40. 18.
70. 19.5
110. 29.
154. 50.
180. 69.
200. 89.
222. 120.
EXECUT
```

Example #1 - Output File

** PCSTABL5 **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:	5/31/85
Time of Run:	2:44 pm
Run By:	Jim Carpenter
Input Data Filename:	Example1.in
Output Filename:	Example1.out
Plotted Output Filename:	Example1.plt

PROBLEM DESCRIPTION PCSTABL5 Example Problem #1 Using Spencer's Method

BOUNDARY COORDINATES

3 Top Boundaries
3 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	20.00	10.00	20.00	1
2	10.00	20.00	210.00	120.00	1
3	210.00	120.00	300.00	120.00	1

ISOTROPIC SOIL PARAMETERS

1 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	125.0	125.0	300.0	40.0	.50	.0	1

Trial Failure Surface Specified By 8 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	10.00	20.00
2	40.00	18.00
3	70.00	19.50
4	110.00	29.00
5	154.00	50.00
6	180.00	69.00
7	200.00	89.00
8	222.00	120.00

Circle Center At X = 42.1 ; Y = 276.0 and Radius, 258.0

Spencer`s Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
13.00	1.255	1.038
19.50	1.173	1.083
25.67	1.000	1.135
22.79	1.101	1.110
21.55	1.132	1.099
22.43	1.110	1.107
22.54	1.108	1.108

Factor Of Safety For The Preceding Specified Surface = 1.108
Spencer`s Theta = 22.54

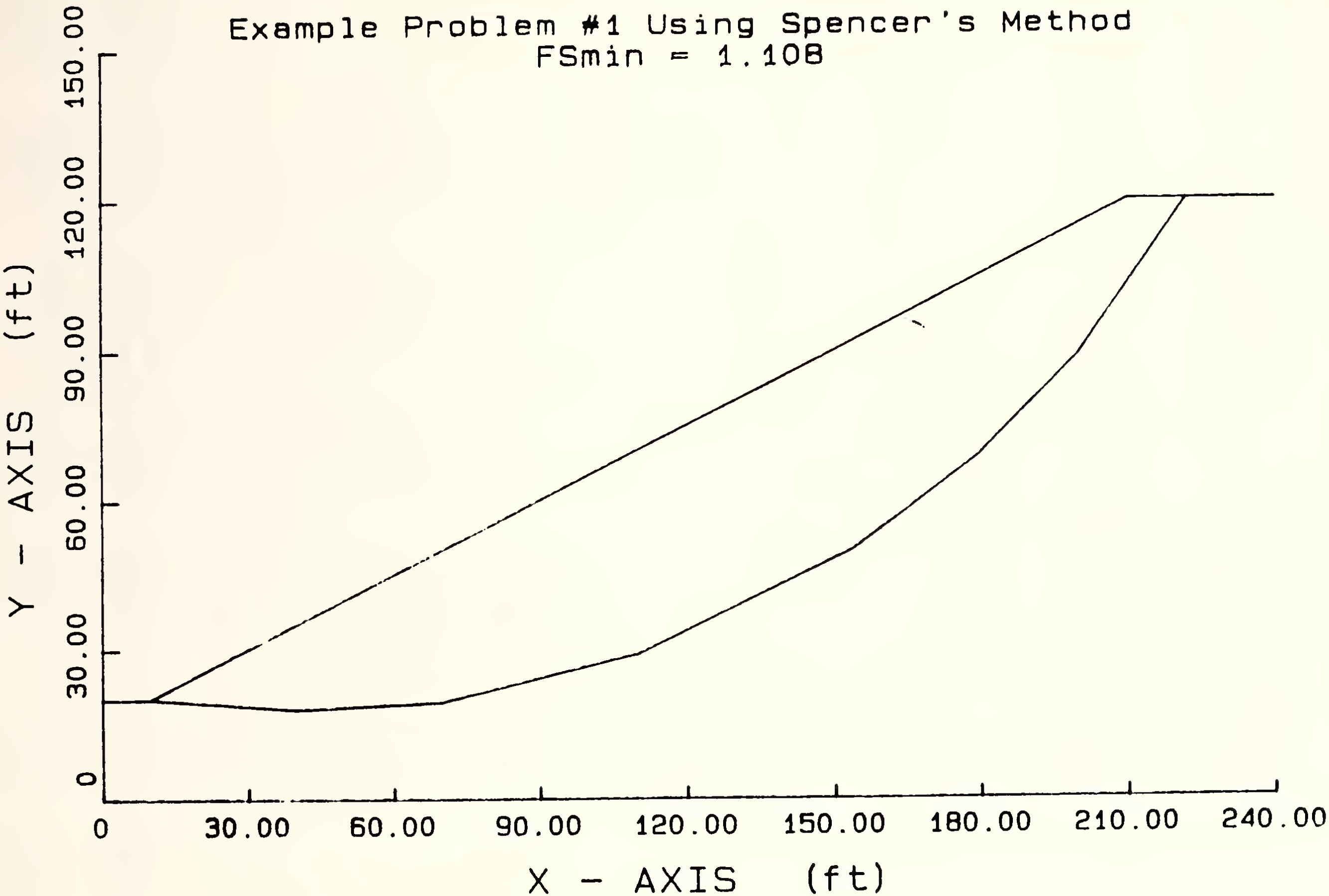
Factor Of Safety Is Calculated By Spencer`s Method of Slices

*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (lbs)
1	40.00	25.22	.425	39762.
2	70.00	30.34	.355	94091.
3	110.00	42.89	.339	131020.
4	154.00	63.94	.332	107077.
5	180.00	81.02	.334	65349.
6	200.00	98.35	.360	26506.
7	210.00	111.03	.469	8094.
8	222.00	115.18	.000	2235.

```
           Y            A     X     I     S            F     T

            .00     37.50     75.00    112.50   150.00    187.50
X       .00 +----*----+---------+---------+---------+---------+
            -
            -    *
            -
            -
            -
      37.50 +    S
            -
            -
            -
            -
            -    S
A     75.00 +
            -
            -
            -
            -
            -
X    112.50 +       S
            -
            -
            -
            -
            -
I    150.00 +
            -            S
            -
            -
            -
            -                 S
S    187.50 +
            -
            -                       S
            -
            -                               *
            -
     225.00 +                               S
            -
            -
            -
            -
            -
F    262.50 +
            -
            -
            -
            -
            -
T    300.00 +                               *
```


Example Problem #1 Using Spencer's Method
FSmin = 1.108
Y - AXIS (ft)
0
30.00
60.00
90.00
120.00
150.00
X - AXIS (ft)
0
30.00
60.00
90.00
120.00
150.00
180.00
210.00
240.00

Example #2 - Input File

```
PROFIL
PCSTABL5 Example Problem #2 Using Spencer's Method
6 5
0. 68. 22. 67. 1
22. 67. 38. 63. 1
38. 63. 101. 88. 1
101. 88. 138. 103. 2
138. 103. 205. 110. 2
101. 88. 205. 99. 1
SOIL
2
116.4 124.2 500. 14. 0. 0. 1
116.4 116.4 0. 0. 0. 0. 1
WATER
1 0.
9
0. 68.
22. 67.
38. 63.
63. 73.
83. 78.
104. 82.
122. 85.
140. 87.
205. 93.
LIMITS
10 8
0. 15. 29. 24.
29. 24. 51. 26.
51. 26. 78. 56.
78. 56. 94. 65.
94. 65. 113. 64.
113. 64. 133. 56.
133. 56. 161. 58.
161. 58. 205. 76.
63. 73. 93. 67.
93. 67. 138. 103.
SPENCR
22.
CIRCL2
3 25
38. 50. 138. 170.
0. 10. 0. -25.
```

Example #2 - Output File

** PCSTABL5 **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:	5/31/85
Time of Run:	3:00 pm
Run By:	Jim Carpenter
Input Data Filename:	Example2.in
Output Filename:	Example2.out
Plotted Output Filename:	Example2.plt

PROBLEM DESCRIPTION PCSTABL5 Example Problem #2 Using Spencer's Method

BOUNDARY COORDINATES

5 Top Boundaries
6 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	68.00	22.00	67.00	1
2	22.00	67.00	38.00	63.00	1
3	38.00	63.00	101.00	88.00	1
4	101.00	88.00	138.00	103.00	2
5	138.00	103.00	205.00	110.00	2
6	101.00	88.00	205.00	99.00	1

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	116.4	124.2	500.0	14.0	.00	.0	1
2	116.4	116.4	.0	.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 9 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	68.00
2	22.00	67.00
3	38.00	63.00
4	63.00	73.00
5	83.00	78.00
6	104.00	82.00
7	122.00	85.00
8	140.00	87.00
9	205.00	93.00

Searching Routine Will Be Limited To An Area Defined By 10 Boundaries
Of Which The First 8 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	.00	15.00	29.00	24.00
2	29.00	24.00	51.00	26.00
3	51.00	26.00	78.00	56.00
4	78.00	56.00	94.00	65.00
5	94.00	65.00	113.00	64.00
6	113.00	64.00	133.00	56.00
7	133.00	56.00	161.00	58.00
8	161.00	58.00	205.00	76.00
9	63.00	73.00	93.00	67.00
10	93.00	67.00	138.00	103.00

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

75 Trial Surfaces Have Been Generated.

25 Surfaces Initiate From Each Of 3 Points Equally Spaced
Along The Ground Surface Between X = 38.00 ft.
and X = 50.00 ft.

Each Surface Terminates Between X = 138.00 ft.
and X = 170.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -25.0 And .0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By Spencer's Method * *

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.92	61.71
3	57.90	61.17
4	67.90	61.38
5	77.85	62.35
6	87.70	64.07
7	97.40	66.53
8	106.88	69.71
9	116.03	73.59
10	124.95	78.17
11	133.5[illegible]	83.40
12	141.[illegible]	89.26
13	149.25	95.71
14	156.38	102.72
15	158.49	105.14

Circle Center At X = 60.1 ; Y = 193.5 and Radius, 132.4

*** FOS = 1.375 Spencer's Theta = 17.52 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.82	61.12
3	57.78	60.20
4	67.78	60.26
5	77.73	61.29
6	87.53	63.28
7	97.08	66.22
8	106.31	70.08
9	115.12	74.81
10	123.43	80.38
11	131.15	86.73
12	138.22	93.80
13	144.57	101.53
14	146.13	103.85

Circle Center At X = 62.2 ; Y = 162.7 and Radius, 102.6

*** FOS = 1.377 Spencer`s Theta = 17.94 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.91	61.64
3	57.89	61.08
4	67.89	61.32
5	77.83	62.36
6	87.67	64.19
7	97.32	66.80
8	106.73	70.18
9	115.54	74.30
10	124.57	79.14
11	132.93	84.66
12	140.60	90.84
13	148.15	97.62
14	154.72	104.75

Circle Center At X = 59.9 ; Y = 185.8 and Radius, 124.8

*** FOS = 1.377 Spencer`s Theta = 18.00 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.93	61.83
3	57.92	61.31
4	67.92	61.44
5	77.89	62.23
6	87.78	63.67
7	97.56	65.76
8	107.18	68.49
9	116.61	71.84
10	125.79	75.79
11	134.69	80.35
12	143.28	85.47
13	151.51	91.15
14	159.35	97.36
15	166.77	104.06
16	168.86	106.22

Circle Center At X = 60.9 ; Y = 213.8 and Radius, 152.5

*** FOS = 1.377 Spencer`s Theta = 16.64 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.93	61.82
3	57.92	61.33
4	67.92	61.52
5	77.88	62.39
6	87.76	63.94
7	97.51	66.17
8	107.08	69.05
9	116.44	72.58
10	125.53	76.75
11	134.31	81.52
12	142.75	86.89
13	150.80	92.82
14	158.43	99.29
15	165.17	105.84

Circle Center At X = 60.2 ; Y = 207.5 and Radius, 146.2

*** FOS = 1.377 Spencer`s Theta = 17.20 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.79	60.95
3	57.74	59.93
4	67.74	59.93
5	77.68	60.96
6	87.47	63.00
7	97.00	66.04
8	106.16	70.05
9	114.86	74.97
10	123.01	80.77
11	130.52	87.37
12	137.32	94.71
13	143.32	102.71
14	143.86	103.61

Circle Center At X = 62.7 ; Y = 156.9 and Radius, 97.1

*** FOS = 1.383 Spencer`s Theta = 17.81 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.88	61.44
3	57.86	60.78
4	67.85	61.02
5	77.79	62.16
6	87.58	64.19
7	97.15	67.09
8	106.42	70.84
9	115.32	75.41
10	123.76	80.76
11	131.70	86.85
12	139.05	93.63
13	145.76	101.04
14	148.02	104.05

Circle Center At X = 60.2 ; Y = 171.8 and Radius, 111.0

*** FOS = 1.391 Spencer`s Theta = 18.16 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.95	62.00
3	57.94	61.63
4	67.94	61.88
5	77.90	62.76
6	87.79	64.26
7	97.56	66.38
8	107.18	69.10
9	116.62	72.42
10	125.82	76.32
11	134.77	80.79
12	143.42	85.81
13	151.73	91.37
14	159.69	97.43
15	167.24	103.98
16	169.61	106.30

Circle Center At X = 58.9 ; Y = 221.4 and Radius, 159.8

*** FOS = 1.394 Spencer`s Theta = 16.75 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.00	63.00
2	47.89	61.55
3	57.88	60.96
4	67.87	61.25
5	77.81	62.41
6	87.60	64.44
7	97.18	67.31
8	106.47	71.00
9	115.40	75.50
10	123.91	80.75
11	131.93	86.73
12	139.39	93.39
13	146.24	100.67
14	148.98	104.15

Circle Center At X = 59.6 ; Y = 175.4 and Radius, 114.4

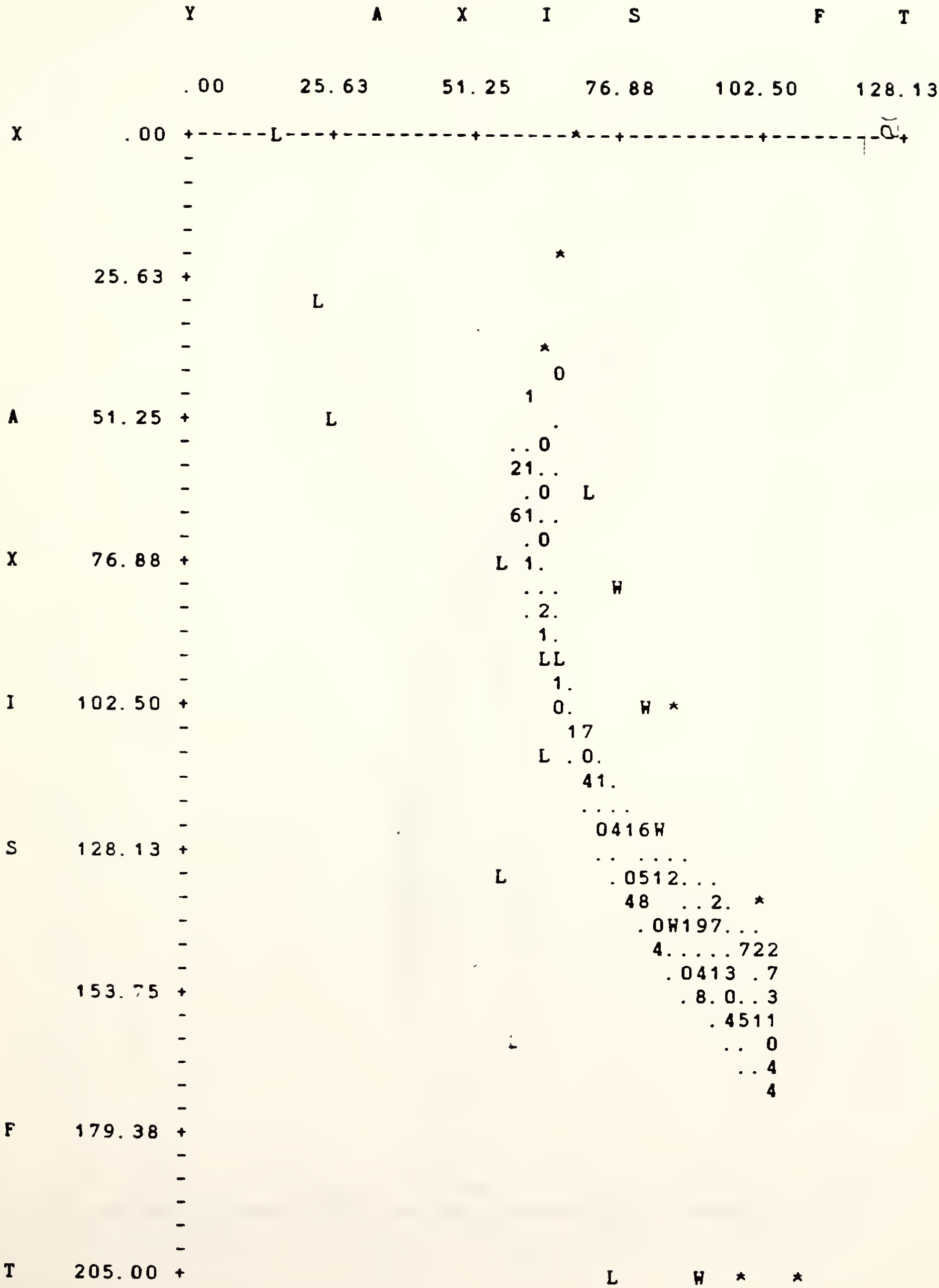
*** FOS = 1.395 Spencer`s Theta = 18.21 ***

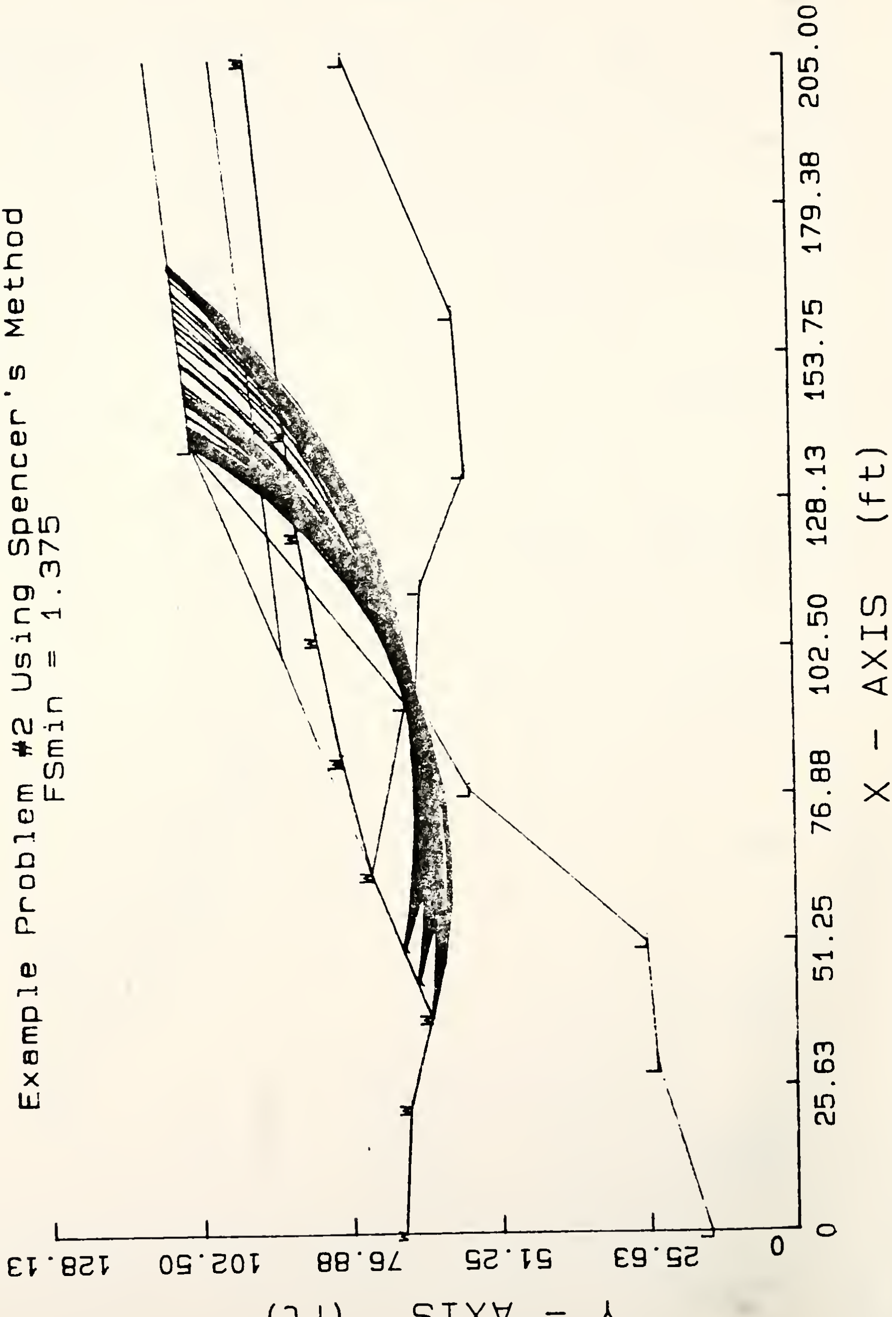
Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	44.00	65.38
2	53.86	63.73
3	63.83	62.88
4	73.83	62.84
5	83.80	63.62
6	93.67	65.20
7	103.38	67.58
8	112.87	70.74
9	122.07	74.66
10	130.92	79.31
11	139.37	84.66
12	147.35	90.68
13	154.82	97.33
14	161.73	104.57
15	162.53	105.56

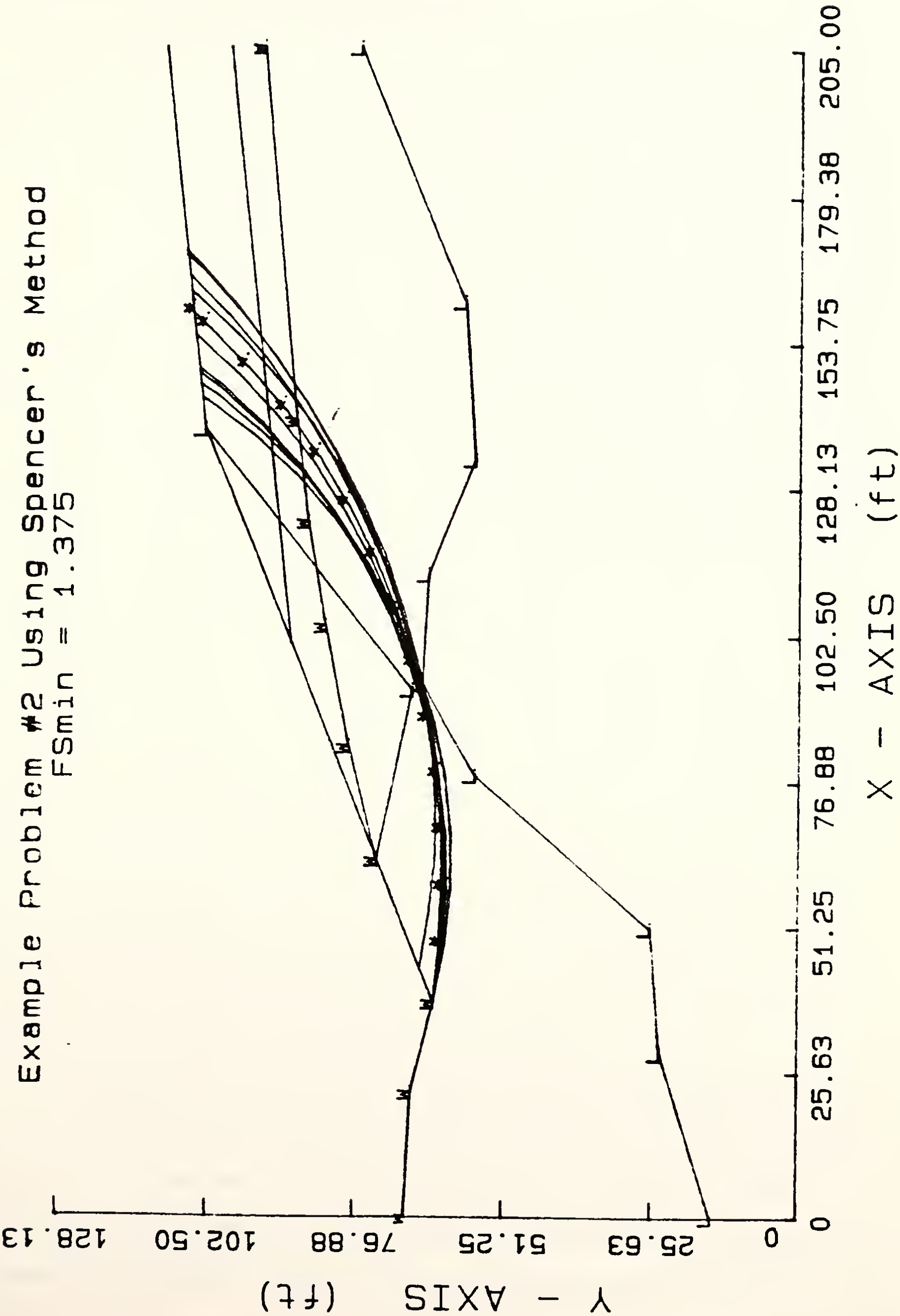
Circle Center At X = 69.3 ; Y = 185.9 and Radius, 123.1

*** FOS = 1.397 Spencer`s Theta = 16.78 ***


Y AXIS FT
.00 25.63 51.25 76.88 102.50 128.13
X AXIS FT
.00
25.63
51.25
76.88
102.50
128.13
153.75
179.38
205.00



Example Problem #2 Using Spencer's Method
FSmin = 1.375
X - AXIS (ft)
Y - AXIS (ft)
0
25.63
51.25
76.88
102.50
128.13
153.75
179.38
205.00



Example Problem #2 Using Spencer's Method
FSmin = 1.375
X - AXIS (ft)
Y - AXIS (ft)
0
25.63
51.25
76.88
102.50
128.13
153.75
179.38
205.00

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III. MODIFICATION OF TIEBACK INPUT

The tieback input option has been modified to allow for the input of concentrated loads applied to a horizontal ground surface boundary. In addition, concentrated loads may now be inclined at an angle between 0 and 180 degrees from the horizontal. The input parameters for a tieback load have been changed to also include the input of the X coordinate of the load applied to the ground surface. Previously, only the Y coordinate was required. Either the X coordinate of the point of application of the tieback load can be specified and the Y coordinate calculated, or the Y coordinate can be specified and the X coordinate calculated. If the user desires, both the X and Y coordinates may be input.

If only the X coordinate is specified, a value of zero must be input for the Y coordinate. When the program encounters a zero Y coordinate, it will automatically calculate the proper Y coordinate for the X coordinate and boundary specified. Likewise, if only the Y coordinate is specified, a value of zero must be input for the X coordinate. When the program encounters a zero X coordinate, it will automatically calculate the proper X coordinate for the Y coordinate and boundary specified.

The user may input both the X and Y coordinates of the point of application of the tieback load on the ground surface boundary. However, the coordinates specified must be sufficiently accurate so that the program will recognize an intersection of the X and Y coordinates specified with the ground surface boundary specified. If the difference between the coordinates specified by the user and the coordinates calculated by the program is greater than 0.001, then an error message will be displayed, and the program execution stopped.

III.1 Revised TIES Input Format

The revised tieback input format is as follows:

COMMAND CARD	TIES	Command Code
DATA CARD	Integer	Number of tieback loads
DATA CARD	Integer	Boundary number where tieback load is applied
	Real	X coordinate of the point of application of tieback load (ft) or (m)
	Real	Y coordinate of the point of application of tieback load (ft) or (m)
	Real	Load per tieback (lbs) or (kg)
	Real	Horizontal spacing between tiebacks (ft) or (m)
	Real	Inclination of tieback load as measured clockwise from the horizontal plane (deg)
	Real	Free length of tieback (ft) or (m) (Equal to zero if other than a tieback load)

Note: Repeat preceding data card for each tieback load.

III.2 Revised TIES Input Restrictions

For completeness, all TIES input restrictions are given below. However, only input restrictions #1 and #3 have been modified.

1. The point of application of a tieback on the ground surface may not be at a ground surface boundary node. Use a slight offset from the node, (i.e. 70.01 instead of 70).

2. No more than 10 tieback loads can be specified; however, they can be in any order.

3. The inclination of a tieback must be equal to or greater than zero degrees and less than 180 degrees as measured clockwise from the horizontal.

4. The horizontal spacing between tiebacks must be greater than or equal to 1 ft (or 1 metre if using SI units).

5. The length of a tieback must be equal to or greater than zero ft. Zero is used for loads other than tieback type of loads.

III.3 Revised TIES Error Codes

For completeness, all TIES error codes are given below. However, only tieback error codes TI04 and TI05 have been modified:

TI01 - An attempt has been made to suppress or reactivate undefined tieback loads. Data must be defined by a prior use of command TIES before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to their use, whether the data are active or suppressed.

TI02 - The number of tieback loads specified exceeds 10. The problem must either be redefined so fewer tieback loads are used, or dimensioning of the program must be increased to accommodate the problem as defined.

TI03 - A negative coordinate has been specified for the tieback load indicated or the calculated Y coordinate of the end of the tieback is negative. All problem geometry must be located within the 1st quadrant.

TI04 - The inclination limits have been exceeded for the tieback load indicated. The inclination of a tieback load must be equal to or greater than zero (deg) and less than 180 (deg) as measured clockwise from the horizontal.

TI05 - The point of application of the tieback load specified does not lie on the ground surface boundary specified. Check the boundary number specified and the X and Y coordinates of the point of application of the tieback load indicated.

TI06 - The horizontal spacing between tiebacks for the row of tiebacks indicated is incorrect. The horizontal spacing between tiebacks must be greater than or equal to 1 ft (or 1 metre if using SI units).

TI07 - The length of the tieback indicated is incorrect. The length of a tieback must be greater than or equal to zero (ft). Zero is used for loads other than tieback type of loads.

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IV. INTRODUCTION TO PCSTABL5

IV.1 PCSTABL5 Versions

Two versions of PCSTABL5 are available for IBM compatible microcomputers.

Version 1.87 runs on any IBM compatible machine with the optional Intel 8087 Math Co-Processor. The program requires the Intel 8087 Math Co-Processor and will not run on IBM compatible machines without the 8087 math coprocessor. Version 1.87 has been compiled to utilize the Intel 8087 Math Co-Processor during execution which significantly enhances execution time.

Version 1.88 is supplied for those users who do not have the Intel 8087 Math Co-Processor. This version will run on any IBM compatible machine, however it is significantly slower than version 1.87 since it does not utilize the Intel 8087 Math Co-Processor. Version 1.88 will run on a machine with or without an 8087 coprocessor, however performance on a machine with an 8087 coprocessor will be the same as that on a machine without an 8087 coprocessor.

For faster execution on machines without the 8087 math coprocessor, the 1.88 version has been compiled using an alternate math library which sacrifices a small amount of precision in return for faster execution. The amount of error is very small and is not significant for engineering purposes, however results will vary somewhat from the 1.87 version.

Version 1.87 is strongly recommended since it will run 3 to 5 times faster than version 1.88 and does not sacrifice any accuracy. For example, a moderately complex problem which generates and analyzes 100 failure surfaces using the Simplified Bishop method of slices takes approximately 4 minutes to run using the 8087 version (version 1.87), while the same problem takes approximately 12 minutes to run using the non-8087 version (version 1.88).

IV.2 Comparison of PCSTABL5 to STABL5

PCSTABL5 is a microcomputer version of the mainframe STABL5 program. PCSTABL5 contains all the options and capabilities of STABL5 including:

- Simplified Janbu, Simplified Bishop, and Spencer's method of slices
- Isotropic and anisotropic soil parameters
- Piezometric water surfaces
- Specific surface or random search surface generation
- Circular, random or block potential failure surfaces
- Tieback, surcharge and earthquake loads

The only notable difference between PCSTABL5 and STABL5 is that the random number generator from STABL3 has been utilized in PCSTABL5, since the random number generator used in STABL5 is not compatible with the IBM microcomputer. Therefore, slight differences may be noticed in the failure surfaces generated and the factors of safety calculated, when comparing the results obtained from PCSTABL5 and STABL5.

The variable definitions have been removed from the source code listing to save storage space and are included in Appendix A. In addition, the source code has been renumbered.

Plotting routines are also available for driving the Hewlett-Packard HP-7470A two-pen plotter and the HP-7475A six-pen plotter and will be discussed in Section VI.

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V. RUNNING PCSTABL5

V.1 Hardware and Software Requirements

The following is a list of the minimum hardware requirements for operating PCSTABL5.

1. One IBM or IBM compatible microcomputer
2. 256 kilobytes of random access memory
3. One double-sided, double density disk drive
4. One 80 column monochrome display
5. One dot matrix printer (11 in. or 17 in. wide carriage)

The following hardware items are optional for operating PCSTABL5, but are strongly recommended for maximum operating efficiency. These items are discussed further in other sections.

1. One Intel 8087 Math Co-Processor
2. One Hewlett-Packard 7470A or 7475A pen plotter

PCSTABL5 will run on machines using any IBM or MS-DOS disk operating system (DOS), including DOS versions 1.0 to 3.0. Software requirements for using PCSTABL5 include:

1. A line editor or word processor for creating input files,
2. A BASIC interpreter (IBM-BASIC or GW-BASIC: Only required if using optional plotting routine, PLOTSTBL)

Color monitors, hard disk drives, other types of printers, additional memory space and the like, may enhance the efficiency of PCSTABL5, but are not required.

V.2 Diskette Contents

PCSTABL5 is supplied on two 5 1/4 inch double-sided, double-density, floppy diskettes, and one single-sided, double-density, floppy diskette. The contents of these diskettes are listed below:

DISK #1:

PCSTABL5.EXE	Executable Program
EXAMPLE1.IN	Example Input Files
EXAMPLE2.IN	
EXAMPLE1.OUT	Example Output Files
EXAMPLE2.OUT	
EXAMPLE1.PLT	Example Plot Files
EXAMPLE2.PLT	
PLOTSTBL.BAS	BASIC Plotting Program

DISK #2:

587STABL5.FOR	
587READ1.FOR	
587READ2.FOR	
587RAND.FOR	FORTRAN Source Code
587SURF.FOR	
587FACT.FOR	

DISK #3:

587MISC.FOR	FORTRAN Source Code
587PLOT.FOR	
587SPENC.FOR	

The FORTRAN source code of PCSTABL5 has been divided into the nine files listed above. Source code files for the 1.87 version have an 587 prefix, while source code files for the 1.88 version have an 588 prefix. These files were compiled and linked together into the executable program PCSTABL5.EXE using the Microsoft FORTRAN compiler, version 3.2. The Microsoft compiler however is not required for running the program, and is only required if the user makes changes in the program. Note that only DISK #1 is required to run PCSTABL5.

It is strongly recommended that the user create backup copies of the original diskettes supplied, and use these copies for day-to-day use, while saving the original diskettes for permanent storage.

V.3 Creation of Input Files

Input files for PCSTABL5 utilize free-format data entry, as used by other versions of STABL. Input files may be created using a line editor, text editor, or a word processor. Since word processors generally store format characters along with the text, input files must be saved without formatting so that format characters will not be encountered when running the program. If such characters are encountered, execution errors will result.

The user is referred to the "STABL User Manual", "Introduction to Slope Stability Analysis with STABL4", and other sections of this manual for proper formatting of input data.

V.4 Running PCSTABL5

Operation of PCSTABL5 is very simple. After creating an input file and storing it on a diskette, simply type "PCSTABL5" in either uppercase or lowercase letters followed by a return. The program will be loaded into memory and will prompt the user for the current date, time, name of the user, input filename, output filename, and filename for subsequent plotting of output. The date, time, and name of the user may be in any form desired. Note that the input and output files do not need to be on the same diskette or disk drive with PCSTABL5, as supplied on DISK #1. Disk drive specifications may be used when invoking PCSTABL5 (i.e., B:PCSTABL5), or when specifying input and output files (i.e., A:EXAMPLE1.OUT). In addition, if an invalid or nonexistent input filename is specified, the operating system will display an error message to the screen and return the user to the DOS prompt.

Filenames for the output file and the plotted output file may be any legal DOS filename. Note that an existing output file on a diskette will be overwritten if an existing output filename is reused. To avoid overwriting existing files, use unique names for each output. All responses to prompts may be uppercase or lowercase characters, including numbers and legal DOS filename symbols.

The program will write the output to the screen and the disk simultaneously. This includes the input parameters, method of analysis, and results. When running a problem which analyzes many surfaces, no output will be written to the screen while trial failure surfaces are being generated and analyzed. After all surfaces have been generated and analyzed, and the ten most critical factors of safety sorted, the program will resume displaying the results to the screen.

If a plotted output file is specified, the program will write commands and sets of coordinates to the disk for subsequent plotting by the PLOTSTBL.BAS program on a Hewlett-Packard plotter. If a plotted output file is not desired, simply type "None" when prompted for the plotted output filename. To save diskette space, only specify a plotted output file for those runs whose outputs will be plotted using PLOTSTBL. Note that plotting is not performed during execution of PCSTABL5. This allows the user to examine the results, and plot only those results which are desired.

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VI. PLOTTING ROUTINE FOR PCSTABL5 - PLOTSTBL

PLOTSTBL is a BASIC program for plotting the graphical output from PCSTABL5 using either a Hewlett-Packard HP-7470A two-pen plotter or an HP-7475A six-pen plotter. PLOTSTBL reads the plotted output file created by PCSTABL5 which contains three letter commands and coordinates for plotting by PLOTSTBL.

VI.1 Hardware and Software Requirements

The only hardware required for plotting graphical output is a Hewlett-Packard HP-7470A or HP-7475A pen plotter. PLOTSTBL is written such that the plotter must be configured at a baud rate of 9600 and connected to serial communication port #1 on the microcomputer. If the user desires to connect the plotter to serial communication port #2, the user must modify line 710 of the PLOTSTBL program to read "com2" instead of "com1". Likewise, if the user desires to use a baud rate other than 9600, the user must replace the "9600" in line 710 of PLOTSTBL with the desired baud rate. For further information on interfacing an HP plotter with the user's specific microcomputer, the user should consult his or her own plotter and microcomputer manuals.

The only software required to run PLOTSTBL is a BASIC interpreter (IBM-BASIC or GW-BASIC), which is normally supplied along with the disk operating system upon purchase of an IBM or IBM compatible microcomputer.

VI.2 Running PLOTSTBL

To run PLOTSTBL, invoke the BASIC interpreter by typing "BASICA", load the PLOTSTBL program by hitting the "F3" (LOAD) key and type "PLOTSTBL". To begin plotting, hit the "F2" (RUN) key and answer the prompts.

The program will prompt the user for the name of the input file to be used for plotting, the first line of the plot title, the second line of the plot title, a request for pen changes, and units for labelling the plot. If pen changes are specified, the program will ask the user if a two or six pen plotter is being used. As with PCSTABL5, disk drive specifications may be used when invoking PLOTSTBL or specifying the input file. The file to be used for plotting must be an existing file on diskette. If the input file specified for plotting is nonexistent, the interpreter will display the error message, "File not found". The user must then hit the "F2" key to restart PLOTSTBL. The title of the plot may contain uppercase and lowercase letters, numbers and symbols, and will appear at the top of the plot.

The user may enhance the plot by specifying that the program prompt the user for pen changes during plotting. This allows the user to use various colors and pen thicknesses during plotting. PLOTSTBL is written so that the user may use any number of pens during plotting and the user is not restricted to the number of pens available on the plotter being used. The program will stop during execution, return the pen to its holder, and prompt the user for a pen change for a particular set of line segments (i.e., boundaries, water surfaces, etc.). The user then specifies the desired pen, and if necessary, replaces the desired pen in the user specified pen holder, and the program continues plotting. The user may also specify that no pen changes are desired. In this case, only pen #1 will be used for the entire plot.

For convenience, an option for specifying the units of the plot is provided. The user may specify that the plot be labelled in either "Feet" or "Meters". Note that specifying either unit does not alter the plot, only the label on the axes of the plot.

For outputs where more than ten surfaces have been generated, two plots will be produced. The first plot will contain all the surfaces generated, while the second plot will contain only the ten most critical surfaces. The user will be prompted to change the paper and place the desired pen for the axes of the plot in pen holder #1. The most critical failure surface plotted will be noted by asterisks (*).

APPENDIX A: Variable And Subroutine Definitions

This appendix contains the variable and subroutine definitions used in the STABL5 and PCSTABL5 FORTRAN source code listings. They are provided here to assist the user in understanding the FORTRAN program source.

The listing of the source code is not provided in this manual, however if the user wishes, he or she may print out the listing from the FORTRAN source code files (on DISK #2 and DISK #3 for the PCSTABL5 version), or contact Purdue University for a complete listing. Since many modifications and improvements have been made to STABL over the years, the source code listing has been renumbered.

A list of non-FORTRAN statements used in the PCSTABL5 8087 version (version 1.87) is included at the end of this appendix.

Var. and Sub. Definitions

a	Array containing the real one digit numbers.
a1	Array used in factor of safety calculation.
a12	Intercept of line through points 1 and 2.
a2	Array used in factor of safety calculation.
a3	Array used in factor of safety calculation.
a34	Intercept of line through points 3 and 4.
a4	Term used in factor of safety calculation.
a5	Term used in factor of safety calculation.
a6	Term used in factor of safety calculation.
ab	Y intercept of the perpendicular bisector of a line segment whose end points are the left termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.
abs	Standard function which determines the absolute value of a number.
ae	Y intercept of the perpendicular bisector of a line segment whose end points are the right termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.
ai	Intercept of boundary (i).
aj	Intercept of boundary (j).
alpha	Array containing values of the angles of the base of each slice.
alpha1	Array containing angles used to calculate the normal and tangential components of the tieback forces at the base of each slice.
ang1	Unmodified counterclockwise direction limit for all initiation points, at which initial line segment of a trial failure surface may project.
ang2	Unmodified clockwise direction limit, for all initiation points, at which initial line segment of a trial failure surface may project.
anglmt	The minimum inclination allowed for a generated trial failure surface.

angs1	Counterclockwise direction limit, which may be modified during generation of surfaces from a particular initiation point, at which initial line segment of a trial failure surface may project.
angs2	Clockwise direction limit, which may be modified during generation of surfaces from a particular initiation point, at which initial line segment of a trial failure surface may project.
aniso	Subroutine that reads, stores, and prints out directional strength parameters of anisotropic soil types.
at	Area of slice subsection above freewater surface.
atan	Standard function that calculates the arctangent of an angle.
axis	An array containing the x axis label.
b	Slope of line defining ground surface where it is intersected by the trial failure surface.
b12	Slope of line through points 1 and 2.
b34	Slope of line through points 3 and 4.
bb	Slope of the perpendicular bisector of a line segment whose end points are the left termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.
be	Slope of the perpendicular bisector of a line segment whose end points are the right termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.
beta	Array containing values of the angle of the top of each slice.
bgrid	Slope of a sliding block box's centerline.
bi	Slope of boundary (i).
bj	Slope of boundary (j).
blksuf	Subroutine which generates individual pseudo-random surfaces of sliding block shape.

Var. and Sub. Definitions

block	Entry of subroutine random which reads search parameters and directs random search for the critical sliding block surface.
block2	Subroutine which generates individual pseudo-random surfaces of sliding block shape with active and passive zones generated according to the rankine theory.
bn	Array containing the boundary numbers corresponding to the point of application of each tieback load.
bnds	An array containing the coordinates of the end points defining the ground surface and subsurface boundaries.
bot	Denominator of factor of safety expression.
bpt	Position on ground surface which each trial surface must exceed when it terminates.
c	Array containing isotropic values of the mohr-coulomb cohesion for each soil type.
ca	Cosine of angle alpha.
cab	Cosine of angle alpha minus beta.
cad	Cosine of angle alpha minus delta.
cat	Array containing values of the cosine of angle alpha minus theta for each slice.
cavt	Cavitation pressure.
cb	Cosine of angle beta.
cblk	Control code which indicates whether block or block2 surface is to generated.
cd	Cosine of angle delt.
cf	Array containing the soil cohesion force for each slice
corr	Array containing correction factors to make the sum of the tieback forces on trial failure surface equal to the applied load for each tieback specified.
cos	Standard function that calculates the cosine of an angle.
cplt	Control code which controls construction of geometry print character array.

csa	Array containing values of mohr-coulomb cohesion for each specified direction range of each anisotropic soil type.
cslice	Cohesion at the base of a slice.
ct	Array containing values of the cosine of angle theta for each slice.
cu	Array containing values of pore pressue constants for each soil type.
date	Character variable that stores the date.
delt	Array containing values of inclination of the boundary load for each slice.
delta	Array containing values of load direction for each boundary load specified.
denoi	Denominator for slope computation of boundary (i).
denoj	Denominator for slope computation of boundary (j).
denom	Denominator of expression checked as a precaution of being zero.
descr	Array containing the second line of the problem description.
dev	Array containing values of angles between the horizontal plane and the line between the point of application of a tieback and the center of the base of a slice for each slice.
direc	Array containing values defining the counterclockwise limit of each direction range of each anisotropic soil type.
dist	Array containing values of the distance between the point of application of a tieback and the center of the base of a slice.
dtheta	Change in direction between two adjacent line segments of a circular trial failure surface.
dummy	Dummy variable used in call of subroutine reader when an integer is to be read.
dx	Array containing values of the width of each slice.
dy	Vertical component of a scaled boundary load.

Var. and Sub. Definitions

end	Last position on the ground surface at which trial surfaces initiate.
ept	Position on ground surface which each trial surface must not exceed while being generated.
equake	Subroutine that reads in, stores, and prints out earthquake data.
error	Character variable representing current error code.
execut	Subroutine that directs calculation of the factor of safety for a specified failure surface.
f	Critical local factor of safety used to detect a negative normal force acting on a slice.
f1	Largest critical local factor of safety used to detect a negative normal force acting on a slice.
factr	Subroutine which calculates the factor of safety.
ffint	Array containing values of the factor of safety with respect to force equilibrium whose sum of the resultants of the interslice forces is equal to zero for a given values of theta.
ffnew	Array containing the value of the factor of safety with respect to force equilibrium for a given value of Spencer's theta.
ffsm	Array containing the values of the factors of safety for the ten most critical trial failure surfaces of those generated and examined using Spencer's method.
fint	Array containing values of the factor of safety calculated at the intersection of the two lines approximating the factor of safety curves with respect to force and moment equilibrium versus the angle of the interslice forces.
flag	Flag used to control calculation of the y coordinate of the base of each slice.
float	Standard function that converts an integer number to a real number.
fmint	Array containing values of the factor of safety with respect to moment equilibrium whose sum of the moments of the resultant interslice forces is equal to zero for a given values of theta.

fmnew	Array containing the value of the factor of safety with respect to moment equilibrium for a given value of Spencer's theta.
fnamein	Character variable which stores the name of the input file.
fnameout	Character variable which stores the name of the output file.
fnew	New factor of safety used during iterative process.
fold	Old factor of safety used during iterative process.
fos	Factor of safety
frtyfv	45 degrees in radians.
fs	Factor of safety.
fsm	Not used - Found in some earlier versions.
fspenc	Subroutine which calculates the factor of safety and line of thrust using Spencer's method of slices.
fss	Array containing values of the factor of safety for the ten most critical trial surfaces of those generated and examined.
gamma	Array containing values of the total unit weight for each soil type.
gsat	Array containing values of the saturated unit weight for each soil type.
hghteq	Array of the values of the hight of the centroid of the horizontal earthquake forces above the base of each slice.
hight	Array containing the heights of the slices.
hp	Control code which controls construction of output file for plotting with a plotting device.
hthr	Height of the line of thrust above the center of the base of a slice.
htslic	Vertical height of a slice.
htthr	Ratio of the vertical height of the line of thrust above the base of a slice to the vertical height of a slice.
i	Index variable for array subscripting.

Var. and Sub. Definitions

ia Array containing the integer one digit numbers.

iangl Control code signals whether trial surface initiation angles have been specified or not.

iblk Control code which activates generation of a sliding block surface.

iblk2 Control code which activates generation of a sliding block surface with rankine active and passive wedges.

icirc Control code which directs generation of circular or irregular surfaces.

idummy Dummy variable used in call of subroutine reader when a real number is to be read.

iexit Control code which terminates execution, if data is inconsistant with the requirements of the program.

iff Control code which controls calculation of factor of safety with respect to force equilibrium using Spencer's method.

ifm Control code which controls calculation of factor of safety with respect to force equilibrium using Spencer's method.

ifix Standard function that converts a real number to a integer number.

ii Index variable for array subscripting.

ij Index variable for array subscripting.

ilimit Control code which activates portions of the program affected by searching limits established by subroutine limits.

inclin Array containing values of tieback inclination as measured clockwise from the horizontal plane for each tieback load specified.

incre Spacing between the trial surface initiation points.

ints Control code which signals whether an intersection has occurred or not.

intsc2 Subroutine which determines whether or not a line segment and a vertical line intersect and calculates the coordinates of the intersection.

intsc3	Subroutine which determines whether or not a line segment and a horizontal line intersect and calculates the coordinates of the intersection.
intsct	Subroutine which determines whether or not two line segments intersect and calculates the coordinates of the intersection.
iplot	Control code which controls translation of axes for plotted output.
iprof	Control code used for checking profil sequence requirement.
ir	Control code which determines whether a number read is to be handled as a real number or as an integer.
iread	Control code which prompts reading a new line of data.
isearc	Control code which activates portions of the program affected by the searching subroutine random.
isoil	Control code which indicates definition of isotropic soil data.
isort	Control code used to direct sorting of trial surfaces.
ispenc	Control code which activates portions of the program which calculates the factor of safety using Spencer's method of slices.
istr	Control code which activates portions of the program handling anisotropic strength condition.
isum	Integer number that is assembled.
isurc	Control code which activates portions of the program handling the surcharge loads specified by subroutine loads.
isurf	Control code which indicates definition of specified trial failure surface
ities	Control code which activates portions of the program handling the tieback anchor loads specified by subroutine ties.
itn	Variable used to temporary store the value of an index variable used for array subscripting.
itp	Array containing soil type indices for each boundary.

Var. and Sub. Definitions

itpa	Array containing the indices of anisotropic soil types.
iwat	Control code which activates portions of the program handling the water surface specified by subroutine water.
ix	Horizontal position of point within plot array.
ixx	Stores value of ix.
iy	Vertical position of point within plot array.
iyy	Stores value of iy.
j	Index variable for array subscripting.
j2	Value of j rounded down to an even integer.
jab	Subscript of the last profile boundary used to check for intersection with the last linesegment generated on the active portion of the trial failure surface.
jb	Subscript of last boundary, defining the ground surface, to be used for determining whether a sliding block box lies entirely below the ground surface.
ji	Subscript of last boundary, defining the ground surface, to be used for determining the y coordinate of the intersection of the left termination limit with the ground surface.
jj	Subscript of last ground surface boundary used for calculation of the y coordinate of an initiation point.
jp	Subscript of the last profile boundary used to check for intersection with vertical line through the last point generated on the trial failure surface.
jpb	Subscript of the last profile boundary used to check for intersection with the last linesegment generated on the passive portion of the trial failure surface.
js	Subscript of last ground surface boundary used to determine the y coordinate of the beginning or end of a surcharge boundary load.
jt	Subscript of the last ground surface boundary used to check for an intersection of a trial failure surface with the defined ground surface.
jtn	Variable used to temporarily store the value of an index variable used for array subscripting.

jtt	Subscript of the last ground surface boundary used to check for an intersection of a redefined trial failure surface with the ground surface.
jw	Array containing the subscript of last point defining each piezometric surface, used to determine the intersection of the centerline of a slice with the piezometric surface.
jww	Stores value of jw.
k	Index variable for array subscripting.
k1	k-1
k2	Value of k rounded down to an even integer.
kcoef	Horizontal earthquake coefficient.
kd	Decimal location.
kd1	kd - 1
keyw	Character array of keywords used to compare with commands directing control of the program by user.
kf	Location of last digit in number.
ki	Location of first digit in number.
ki	Reduction factor for Spencer's theta for upper slices of sliding mass (subroutine FSPENC only).
kk	Index variable for array subscripting.
l	Index variable for array subscripting.
lb	Y coordinate of slice base.
length	Array containing values of the length of each tieback specified.
limit	Array containing the coordinates of the end points defining each boundary used to define the extent of searching by subroutine random.
limits	Subroutine that reads in, stores, and prints out the limits which bound the area to be searched with subroutine random.
load	Array containing values of uniform load intensity for each boundary load specified.

Var. and Sub. Definitions

loads	Subroutine that reads in, checks, stores, and prints out boundary loading data.
lot	Control code used to calculate the line of thrust using Spencer's method.
m	Array containing the individual characters read from a line of data.
maxl	Maximum intensity of the boundary loads specified.
maxtl	Maximum intensity of the equivalent line loads for all tiebacks specified.
maxx	Maximum x coordinate of any geometry point.
maxy	Maximum y coordinate of any geometry point.
mb	Control code which indicates modified Bishop factor of safety calculation (if mb=1).
mkeyw	Character variable representing the command last read in.
n	Array containing alpha-numeric characters used for comparisons.
name	Character variable which stores the name of the person running the program.
nbnd	Total number of profile boundaries.
nbnd1	nbnd - 1
ncha	Number of soil type changes.
nd	Do loop terminator.
ndirec	Array containing the number of direction ranges for each anisotropic soil type.
ngrid	Number of boxes specified.
nipt	Number of initiation points.
nlim	Number read as number of surface generation limit boundaries specified.
nlimit	Number of surface generation limit boundaries.
nlmt	Number of surface generation limit boundaries which deflect generated surfaces upward.

nn	Variable used to temporary store an array variable for a do statement.
norm	Array containing values of the normal force on the base of each slice of the sliding mass.
np	Array containing number of piezometric surface for each soil type.
npi	Number read as number of piezometric surfaces defined.
npiez	Number of points defining the water surface.
npz	Number of piezometric surfaces defined.
nr	Total number of rejections while attempting to generate a trial failure surface.
nrr	Number of rejections while attempting to generate a circular surface from the second line segment when conflict occures with restrictions on minimum elevation and overturning slip surface.
ns	Number of points defining the last surface generated.
nsa	Number read as number of soil types having anisotropic strength properties.
nsal	Number of soil types having anisotropic strength properties.
nslice	Number of slices that sliding mass is divided into.
nsoi	Number read as number of soil types.
nsoil	Number of soil types specified.
nsuc	Number read as number of boundary loads specified.
nsurc	Number of boundary loads specified.
nsurf	Number of points defining a trial failure surface
nsurfs	Array containing values of the number of points defining each of the ten most critical trial surfaces.
ntie	Number read as number of tieback anchor loads specified.
nties	Number of tieback anchor loads specified.
ntop	Number of ground surface boundaries.

Var. and Sub. Definitions

ntop1	ntop + 1
ntria	Total number of trial failure surfaces generated.
ntrial	Number of trial surfaces generated from each starting point.
p	Array containing values of the boundary load applied to each slice.
perpen	90 degrees in radians.
phi	Array containing isotropic values of the mohr-coulomb angle of internal friction for each soil type.
phia	Array containing values of the mohr-coulomb angle of internal friction for each specified direction range of each anisotropic soil type.
pi	Pi.
pl	A scaled boundary load.
pload	Array containing the values of the tieback anchor point loads applied to the ground surface for each tieback anchor specified.
plotfile	Character variable which stores the name of the output file used for plotting with a plotting device.
plotin	Subroutine which writes control codes and coordinates to the plotted output file.
plt	Array containing the character plot matrix.
pltn	Subroutine which sets up the axes and axis lables for the print character plot.
plttr	Character array containing plotter control codes which are written to plotted output file for directing control of plotter.
postn	Subroutine which determines the position of a scaled coordinate point within the character plot array.
prad	Array containing values of the unresolved tieback force on the base of each slice.
profil	Subroutine that reads in, checks, stores, and prints out profile geometry data.
psum	Array containing values of the sum of the tieback forces on the base of each slice over the whole trail failure surface for the current tieback load.

qf	Array containing values of the sum of the resultant interslice forces on each slice.
qm	Array containing values of the sum of the moments of the resultant interslice forces on each slice.
quit	Subroutine that displays a termination message, and terminates execution of the program.
r	Variable containing a pseudo-random number.
rad5	5 degrees in radians.
radius	Distance between the coordinate points and the center of the simplified Bishop limit equilibrium surface (mb=1).
random	Subroutine that directs random search for the critical irregular or circular surface.
ranf	Function subprogram that generates a pseudo-random number that has a uniform probability of having any value ranging from zero to one.
ransuf	Subroutine which generates individual pseudo-random surfaces of a circular and irregular nature.
rb	Radius of a circle containing the left termination limit at the ground surface and both end points of the initial line segment generated for a circular trial failure surface.
rbx	X coordinate of the center of a circle containing the left termination limit at the ground surface and both end points of the initial line segment generated for a circular trial failure surface.
rby	Y coordinate of the center of a circle containing the left termination limit at the ground surface and both end points of the initial line segment generated for a circular trial failure surface.
rd	Factor for conversion of degrees to radians.
re	Radius of a circle containing the right termination limit at the ground surface and both end points of the initial line segment generated for a circular trial failure surface.
reader	Subroutine that reads integer or real data in free form format.
rex	X coordinate of the center of a circle containing the right termination limit at the ground surface and

	both end points of the initial line segment generated for a circular trial failure surface.
rey	Y coordinate of the center of a circle containing the right termination limit at the ground surface and both end points of the initial line segment generated for a circular trial failure surface.
ru	Array containing values of the pore pressure parameter for each soil type.
s0	Term used in the factor of safety calculation for Spencer's method of slices.
s1	Array containing values used in the factor of safety calculation for Spencer's method of slices.
s2	Array containing values used in the factor of safety calculation for Spencer's method of slices.
s3	Array containing values used in the factor of safety calculation for Spencer's method of slices.
sa	Sine of angle alpha.
sat	Array containing values of the sine of the angle alpha minus theta for each slice.
sb	Sine of angle beta.
sba	Sine of angle beta minus alpha.
sda	Sine of angle delta minus alpha.
scaler	Subroutine which determines the scale for plotting.
scl	Array which contains the tick mark labels.
scle	Scale used for plotting.
sd	Sine of angle delt.
sin	Standard function that calculates the sine of an angle.
slices	Subroutine which divides sliding mass into slices.
slope	Slope in radians of line defining the ground surface where a trial surface initiates.
slp	Slope of line extending from first point on ground surface to either of the bottom corners of the first box specified for a sliding block search.

slpang — Estimated angle of the slope input by the user for use with Spencer's method.

slpb — Slope of a line segment whose end points are the left termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.

slpe — Slope of a line segment whose end points are the right termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.

sltp — Array containing indices of the soil type at the base of each slice.

soil — Subroutine that reads in, stores, and prints out isotropic soil parameters.

soil — Array containing indices of soil type of each subsection within a slice (in sub. wght).

soiltp — Variable containing soil type at the base of a slice.

soilwt — Subroutine that calculates the total weight of a slice subsection.

sort — Subroutine that sorts ten trial failure surfaces by magnitude of factor of safety.

space — Array containing the values of the horizontal spacing between tiebacks for each row of tieback anchors specified.

sphm — Value used in determining the sum of the interslice forces and moments for Spencer's method of slices.

spntht — Array containing the values of Spencer's theta corresponding to the ten most critical trial failure surfaces generated and analyzed.

spthet — Array containing the value of Spencer's theta for each slice. Note: Upper slices have reduced values of Spencer's theta.

sqrt — Standard function that calculates the square root of a number.

ssign — Variable used to handle the sign of the number being assembled.

ssthet — Variable containing the value of Spencer's theta satisfying both force and moment equilibrium for the trial surface being analyzed.

Var. and Sub. Definitions

st	Soil type of subsection.
st	Array containing the values of the sine of angle theta for each slice (subroutine FSPENC only).
start	First position on the ground surface at which trial surfaces initiate.
stheta	Array containing the values of Spencer's theta used during iteration process.
stint	Array containing the values of Spencer's theta at the intersection of the factor of safety curves with respect to force and moment equilibrium.
sum	Real number that is assembled.
sumb	Denominator of first derivative of the factor of safety expression.
sumqf	Array containing values of the sum of the resultant interslice forces on all slices of the sliding mass.
sumqm	Array containing values of the sum of the moments of the resultant interslice forces on all slices of the sliding mass.
sumt	Numerator of first derivative of the factor of safety expression.
surc	Array containing x coordinates of the end points defining the extent of loading.
surf	Array containing the x and y coordinates of points defining the trial failure surface.
surfac	Subroutine that reads in, checks, stores, and prints out data defining an individual trial failure surface.
surfs	Array containing sets of coordinate points defining each of the ten most critical trial surfaces.
switch	Array used to temporarily store the contents of array surf for reordering.
symb	Array which contains the characters that are used for plotting.
symbol	External subroutine that activates the plotting pen to plot characters or on-center symbols.
t	Horizontal water force in the tension crack assumed for Spencer's method of slices.

ta	Tangent of angle alpha.
tal	Integer variable storing the number of trial surfaces generated in a search, used by the external subroutine number.
tan	Standard function that calculates tangens of an angle.
tat	Tangent of angle alpha minus theta.
thet	Angle at which a line segment of a circular surface intersected a surface generation boundary.
theta	Direction of last line segment defining the trial surface.
theta1	Angle spread within which the next line segment of the generating trial surface may project.
theta2	Limiting angle in clockwise direction at which next line segment may project.
thetab	Maximum change in direction allowed between adjacent line segments of a circular trial failure surface with a particular initial line segment.
thetae	Minimum change in direction allowed between adjacent line segments of a circular trial failure surface with a particular initial line segment.
thetal	Minimum inclination allowed for a particular line segment of an irregular trial failure surface.
thetas	Inclination of the initial line segment of a trial failure surface.
thetau	Maximum inclination allowed for a particular line segment of an irregular trial failure surface.
thl	Difference in elevation between the y-coordinate of the line of thrust on the right side of a slice and the y-coordinate of the center bottom of a slice.
ties	Subroutine that reads in, checks, stores, and prints out tieback anchor load data.
time	Character variable which stores the time.
title	Array containing the first line of the problem description.
tl	A scaled equivalent line load for a given tieback.

Var. and Sub. Definitions

tload	Array containing values of equivalent horizontal line loads for each tieback anchor specified assuming a uniform distribution of load to the ground surface between tiebacks.
tnorm	Array containing values of the total tieback load acting normal to the base of each slice for all tieback loads specified.
tol	Tolerance constant to account for machine rounding.
tp	Tangent of angle phi.
tp	Array containing values of the angle phi for each slice of the sliding mass (subroutine fspenc only).
trans	Subroutine which transfers the equivalent line load for each tieback to the base of each slice using Flamants's formulas.
tsurf	Length of line segments defining trial surfaces.
tt	Tangent of the inclination of the initial line segment of a trial failure surface.
tt	Array containing values of the tangent of angle theta for each slice of the sliding mass (subroutine fpsenc only).
ttan	Array containing values of the total tieback load acting tangent to the base of each slice for all tieback loads specified.
ttheta	Array containing values of angles between the line of action of a tieback and the line between the point of application of a tieback and the center of the base of a slice for each slice.
ualpha	Array containing values of the hydrostatic force acting at the base of each slice.
ub	Y coordinate of top of slice.
ubeta	Array containing values of the hydrostatic force acting at the top of each slice.
uwat	Unit weight of water. If 0. is specified, 62.4 pcf is assumed.
vkcoef	Vertical earthquake coefficient.
w	Scaled width of a box for for sliding block search.

water	Subroutine that reads in and prints out the water surface data.
weight	Subroutine which calculates the total weight of each slice.
width	Array containing the values of the width of each box.
wt	Weight of a slice subsection.
wtheq	The product of the weight of a slice and the distance between its base and the centroid of its horizontal earthquake force.
wtt	Array containing values of the weight of each slice.
x	Array containing the x coordinates of the center of the base of each slice.
x1	X coordinate of the projected intersection of two boundary line segments.
x2	X coordinate of second point.
x3	X coordinate of third point.
x4	X coordinate of fourth point.
xb	X coordinate of the midpoint of a line segment whose end points are the left termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.
xcntr	X coordinate of the center of a circular limit equilibrium surface.
xe	X coordinate of the midpoint of a line segment whose end points are the right termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface.
xend	Array containing values of the calculated x coordinate of the end of each tieback specified
xhalf2	X coordinate of the midpoint of the second segment on the limit equilibrium surface.
xint	X coordinate of intersection of two line segments.
xl	Array containing values of the x coordinate of the left end of each box centerline.
xm	x1 - tol

Var. and Sub. Definitions

xp	x1 + tol
xpiez	Array containing x coordinates of points defining water surface.
xr	Array containing values of the x coordinate of the right end of each box centerline.
xthr	X coordinate of the line of slice for a given slice.
xtie	Array containing calculated values of the x coordinate of the point of application on the ground surface of each tieback anchor load specified.
xx	X coordinate of point to be scaled.
y	Y coordinate of intersection of two line segments.
y1	Y coordinate of the projected intersection of two boundary line segments.
y1	Y coordinate of first point.
y2	Y coordinate of second point.
y3	Y coordinate of third point.
y4	Y coordinate of fourth point.
yb	Array containing values of the y coordinate of the base of each slice.
ybpt	Y coordinate of left termination limit at the ground surface.
ycntr	Y coordinate of the center of the limit equilibrium surface.
ye	Y coordinate of the midpoint of a line segment whose end points are the right termination limit at the ground surface and the right end point of the initial line segment of a circular trial failure surface
yend	Array containing values of the calculated y coordinate of the end of each tieback specified
yept	Y coordinate of right termination limit at the ground surface.
ygl	Y coordinate of point on ground surface directly above the left end of a sliding block box.
ygr	Y coordinate of point on ground surface directly above the right end of a sliding block box.

yhalf2	Y coordinate of the midpoint of the second segment on the limit equilibrium surface.
yi	Array containing the y coordinates of intermediate points dividing a slice into subsections.
yint	Y coordinate of intersection of two line segments.
yl	Array containing values of the y coordinate of the left end of each box centerline.
yll	Left top corner of a sliding block box.
ymax	End point of surface generation boundary with the maximum y coordinate.
ymin	Lowest depth to which a trial surface may extend.
ypiez	Array containing y coordinates of points defining water surface.
yr	Array containing values of the y coordinate of the right end of each box centerline.
yrr	Right top corner of a sliding block box.
ysurc	Array containing the calculated y coordinates of the ends of the boundary loads on the ground surface.
yt	Y coordinate of the top of a slice.
ythr	Array containing the values of the Y coordinate of the line of thrust on the right side of each slice of the sliding mass.
ytie	Array containing inputted values of the y coordinate of the point of application on the ground surface of each tieback anchor load specified.
yw	Array containing y coordinate of the piezometric surface for each soil type of a slice.
yy	Y coordinate of point to be scaled.
z	Array containing the values of the interslice forces on the right side of each slice.
zo	Depth of zero active effective stress.

NON-FORTRAN STATEMENTS:

$NOFLOATCALLS A Microsoft FORTRAN Metacommand used during compilation which directs the compiler to create an executable program which optimizes use of the Intel 8087 Math Co-Processor during execution of the program.

COVER DESIGN BY ALDO GIORGINI